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The Russian Wheat Aphid
Sixth Annual Report

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Research Laboratory
Stillwater, Oklahoma

PSWCRL Prog. Rep. 94-001

Contents

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Figure 3 was provided by Dr. David McNeal, APHIS PPQ, Hyattsville, MD.

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Introduction

Although it has been eight years since the detection of the Russian wheat aphid (RWA) in the United States, its status as a serious economic pest of wheat and barley has not diminished. The latest economic data provided by Legg and Amosson[1] show that estimated yield losses attributed to RWA in the western United States during the 1991-92 crop year were 25,536,000 bushels with an estimated value of $74,792,000. This is the second highest yield loss since the collection of RWA economic impact data began in 1987, and 24 times greater than bushels lost in the 1990-91 crop year! As pointed out in last year's report, serious RWA outbreaks will continue to occur when conditions are favorable. During the 1991-92 crop year, 838,000 acres were treated with insecticides for RWA at a cost of $7,598,000. Estimates of cumulative losses for 1987-92 are $413.1 million in direct loss (control costs, yield loss, and grazing loss) and 437.7 million in indirect loss (ripple effects sustained by the regional economy) -- a total loss approaching $850.8 million. Additional information about the economic impact of the RWA in the western United States is presented in Figures 1 and 2.

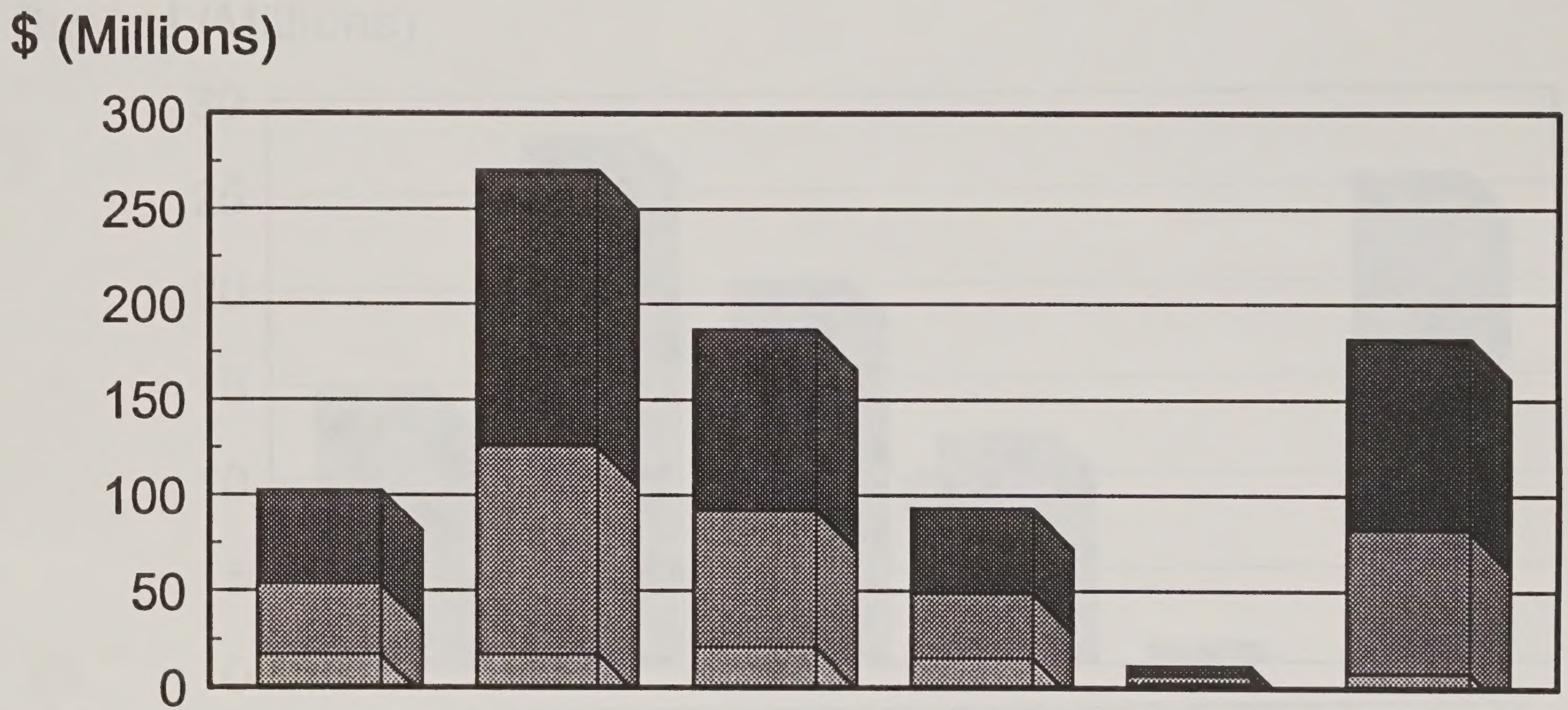
Soon after the original 1986 detection of the RWA in Bailey Co., TX, the pest spread rapidly to the major wheat and barley producing areas of the western United States (Fig. 3) and has probably reached all parts of the country where it is likely to be a problem. Most of the serious infestations and economic losses have occurred west of the 100th meridian. Why the RWA has not become a problem east of this line has generated considerable speculation, but scientific facts to explain this phenomenon remain unavailable.

This is the sixth annual report of research progress on the RWA by the Agricultural Research Service of the USDA. As the report indicates, our research is focused on natural control strategies including biological control and the development of RWA-resistant wheat and barley germplasm lines. Several projects fall within these areas and some overlap. For example, we are increasing our knowledge base in areas such as landscape ecology as it relates to aphid populations. We are also learning more about alternate hosts for the RWA as well as alternate aphid hosts for RWA parasitoids. Our overall goal is to develop improved pest management systems for the RWA.

This report is intended as a brief update on the advances in ARS RWA research that have taken place during the past year. Many of our projects are cooperative with organizations including other ARS scientists and locations, as well as scientists from state agricultural experiment stations and USDA-APHIS. These combined efforts provide an excellent model of a cooperative research endeavor and greatly increase the probability of successfully managing the RWA on a regional basis. Space limitations for this report dictate brevity. Additional information about the RWA or specific projects may be obtained directly from the scientists listed in the individual research reports.

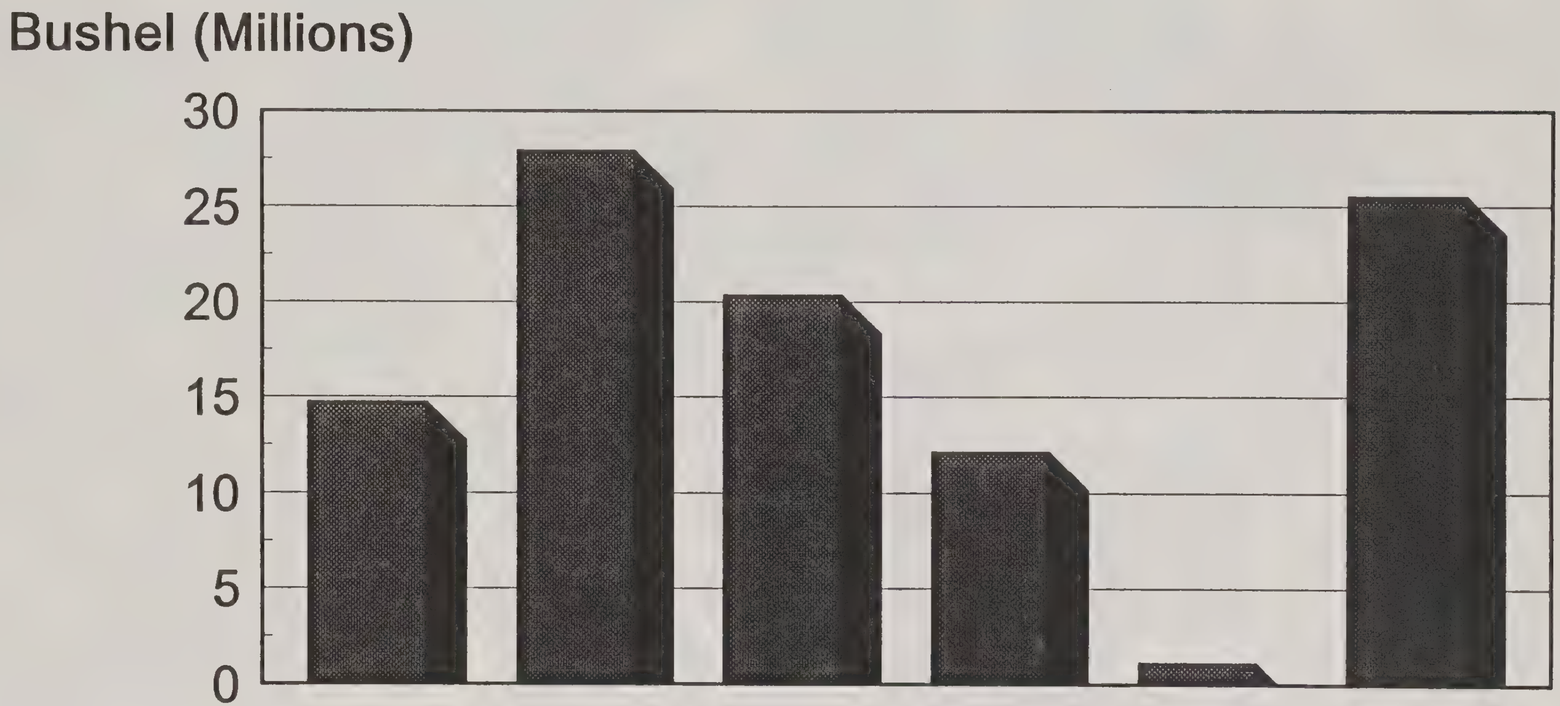
[1] Legg, D. and S. Amoson. 1993. Economic impact of the Russian wheat aphid in the United States: 1991-92. Great Plains Agric. Counc. Pub. 147.

Figure 1. Economic Impact of the Russian Wheat Aphid



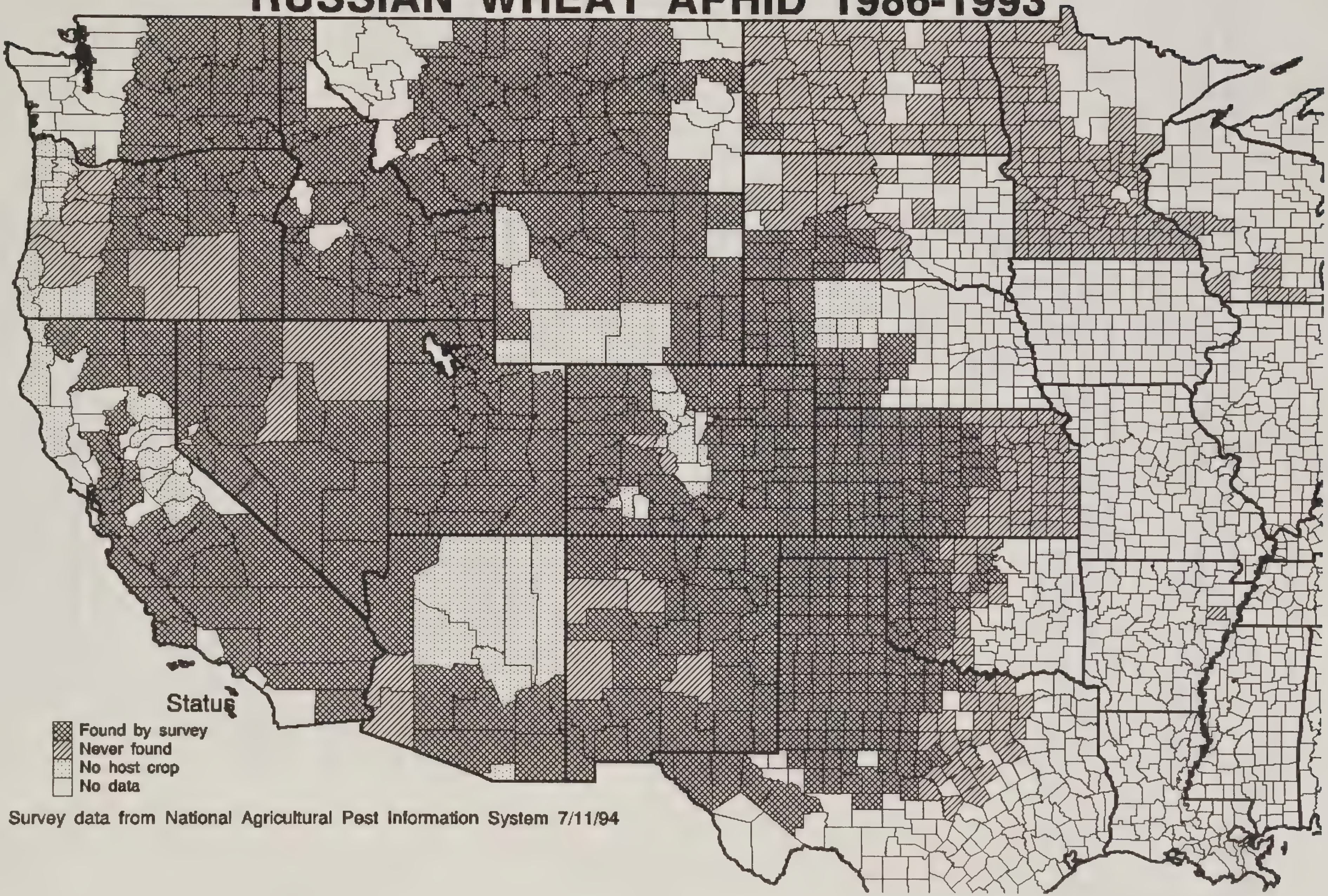
Year	1987	1988	1989	1990	1991	1992
Control Cost	17.2	17.0	20.9	15.4	2.5	7.6
Yield Loss	36.6	108.9	71.2	33.4	3.9	74.8
Indirect Loss	48.7	144.8	94.7	44.5	5.3	99.7

Figure 2. Impact of Russian Wheat Aphid on Small Grain Production



Year	1987	1988	1989	1990	1991	1992
Yield Loss	14.7	27.9	20.3	12.1	1.1	25.5

RUSSIAN WHEAT APHID 1986-1993



Survey data from National Agricultural Pest Information System 7/11/94

Alternate Hosts for Russian Wheat Aphid

Mission: To identify and characterize RWA-resistant germplasm lines that may serve as breeding resources for both cool- and warm-season cereals and turf, range, and conservation grass species.

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Possible sources of RWA resistance in the perennial Triticeae are reported for the first time. Resistance was related to the newly defined and realigned genera of the perennial Triticeae based on genomic composition. We could not correlate the degree of RWA resistance with the genomic system of classification. However, genera within the tribe Triticeae can be loosely grouped into three categories: 1) moderately resistant: *Leymus* and *Elytrigia*; 2) tolerant to moderately susceptible: *Agropyron, Pseudoroegneria, Elymus,* and *Pascopyrum*; and 3) susceptible: *Hordeum* and *Thinopyrum*. Within the tribe Triticeae, the genera *Leymus* and *Elytrigia* are the best sources of resistance. However, within each species, extensive variation for resistant types occurs. Introgression of valuable gene(s) for insect resistance has been achieved by interspecific hybridization between the perennial Triticeae species and the cultivated cereals.

RWA resistance identified in several slender wheatgrass, *Agropyron trachycaulum* (Link) Malte = [*Elymus trachycaulus* (Link) Gould ex Shinners], plant introductions (PIs) may provide genetic variation necessary to breed RWA-resistant wheat cultivars. Seven PIs and the cultivar Pryor slender wheatgrass were considered resistant to RWA. Six PIs (406307, 183009, 440106, 440100, 440102, and 442444) with low damage scores also had low aphid populations and moderate to low leaf-curling scores. All PIs, including the resistant and susceptible entries, had significantly fewer RWAs surviving after 14 days compared with TAM W-101 wheat. All entries tested for antibiosis level were significantly higher for this trait than TAM W-101 wheat. PIs 440100 and 440102 had the highest level of antibiosis, and both has the lowest level of leaf curling. Results of the preference test also indicated that all slender wheatgrass PIs tested were less preferred by RWA in comparison with wheat. Results of these studies indicate that there is a wide genetic diversity in slender wheatgrass. This diversity should be useful in small grain breeding programs.

David Reed (retired) and Dean Kindler surveyed for RWA in Mendoza Province, Argentina, during September 13-18, 1993. We were accompanied by one Chilean and three Argentinian entomologists. Senör Ortego in earlier surveys for RWA in Mendoza Province had identified nine host plants: *Avena sativa,*

Bromus unioloides, Hordeum comosum, H. compresum, H. distichum, H. vulgare, Secale cereale, Triticum aestivum, and one unidentified Graminea. While there, we added *Agropyron elongatum* to the list. It was not difficult to find RWA surviving the winter. In general, overwintering RWA populations were highest on *Bromus unioloides* and *Avena sativa*. In the main cereal growing area of Argentina (Buenos Aires Province and surrounding areas), the presence of the RWA, although not extensively surveyed for, has not been detected, although it has been reported to occur just south of the main cereal growing area. It is feared that if found it will upset the balance between parasites and predators and cereal aphids biocontrol. Presently pesticides are not used in this area, but they may be necessary if RWA becomes economically important.

Publications Since Last Report

Kindler, S.D. 1993. Alternate hosts for Russian wheat aphid, pp. 4-5. *In* R.L. Burton and J.A. Webster (comp.) The Russian wheat aphid, fifth annual report. U.S. Dep. Agric., Agric. Res. Serv. PSWCL Prog. Rep. 93-009.

Kindler, S.D., K.B. Jensen, and T.L. Springer. 1993. An Overview: Resistance to the Russian wheat aphid (Homoptera: Aphididae) within the perennial Triticeae. J. Econ. Entomol. 85:1609-1618.

Kindler, S.D., and T.L. Springer. 1993. Screening for Russian wheat aphid resistance in *Hordeum* species. PSWCL Rep. 93-006. 29 pp.

Kindler, S.D., T.L. Springer, and R.J. Tyrl. 1993. Screening for Russian wheat aphid resistance in *Agropyron* species. PSWCL Rep. 93-001. 48 pp.

Kindler, S.D., T.L. Springer, and R.J. Tyrl. 1993. Screening for Russian sheat aphid resistance in *Elymus* species. PSWCL Rep. 93-002. 15 pp.

Kindler, S.D., T.L. Springer, and R.J. Tyrl. 1993. Screening for Russian wheat aphid resistance in *Secale* species. PSWCL Rep. 93-003. 4 pp.

Kindler, S.D., T.L. Springer, and R.J. Tyrl. 1993. Screening for Russian wheat aphid resistance in *Stipa* species. PSWCL Rep. 93-004. 12 pp.

Kindler, S.D., T.L. Springer, and R.J. Tyrl. 1993. Screening for Russian wheat aphid resistance in *Bromus* species. PSWCL Rep. 93-005. 32 pp.

Presentations

Kindler, S.D., and R.W. Hammon. 1993. Comparison of the host suitability of western wheat aphid with Russian wheat aphid. Annual Meetings, Entomological Society of America.

Host Plant Resistance

Mission: To identify resistance sources, study the nature of this resistance, and cooperate with the Small Grain Germplasm Enhancement program in the development and release of RWA-resistant small grain germplasms.

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Keith Mirkes, Biological Science Technician
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Germplasm Evaluation
To identify new sources of RWA resistance, the systematic germplasm evaluation program has continued. This year, the majority of material evaluated has been wheat; 9,479 wheat accessions were evaluated, and 40 of these accessions were found to be resistant. To date, over 800 wheat lines have been identified as having some level of resistance. The entire ARS National *Hordeum vulgare* collection will have been tested when the current evaluation of 1800 accessions is completed. To date, 38 barley lines have been found to be resistant, and 67 lines were moderately resistant to moderately susceptible. In a cooperative effort, we have conducted RWA resistance tests of advanced material for several barley and wheat breeding programs. Approximately 1200 lines of wheat from an Australian collection have been received for RWA tests.

Other
New techniques were developed for conducting aphid preference/non-preference tests (antixenosis) with individual cut leaves (see Webster et al., 1994). Previous research has indicated that wheat leaf pubescence is not an effective deterrent for the RWA. Recent research has shown that leaf pubescence also has little effect on greenbugs, but is an effective resistance mechanism against the yellow sugarcane ahphid.

International Cooperation
Our laboratory co-hosted the 11th Biennial Plant Resistance to Insects Workshop February 28 - March 2, 1994, and several international participants toured the laboratory during the workshop. Since the last report we also hosted a team of agriculturalists from the People's Republic of China; scientists from the Small Grain Centre, Bethlehem, South Africa; Awarsa College of Agriculture, Ethiopia; International Centre of Insect Physiology, Nairobi, Kenya; Cereal Research Institute, Szeged, Hungary; and the Department of Genetics, University of Cordoba, Spain.

Publications Since Last Report

Webster, J.A. 1993. Host plant resistance, pp. 6-9. *In* R.L Burton and J.A. Webster (comp.) The Russian wheat aphid, fifth annual report. U.S. Dep. Agric., Aric. Res. Serv., PSWCL Prog. Rep. 93-009.

Webster, J.A., F. Dutoit, and T.W. Popham. 1993. Fecundity comparisons of the Russian wheat aphid (Homoptera: Aphididae) in Bethlehem, South Africa, and in Stillwater, Oklahoma. J. Econ. Entomol. 86:544-548.

Webster, J.A., C. Inayatullah, M. Hamissou, and K.A. Mirkes. 1994. Leaf pubescence effects in wheat on yellow sugarcane aphids and greenbugs (Homoptera: Aphididae). J. Econ. Entomol. 87:231-240.

Webster, J.A., D.R. Porter, C.A. Baker, and D.W. Mornhinweg. 1993. Russian wheat aphid (Homoptera: Aphididae) resistance in barley: Effects on aphid feeding. J. Econ. Entomol. 86: 1603-1608.

Small Grain Germplasm Enhancement

Mission: To identify, characterize, and introgress genes conferring RWA resistance for small grain germplasm enhancement.

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RWA-resistant wheat germplasms STARS-9302W and STARS-9303W were released. These hard red facultative germplasms were developed from crosses between an unadapted RWA-resistant parent (PI 149898) and an adapted RWA-susceptible parent. Both of these germplasms were included in the First Uniform Russian Wheat Aphid Field Test (URWAFT); over 5 locations, these two lines were the highest ranked of any of the improved material.

RWA-resistant barley germplasm STARS-9301B was released to breeders in the fall of 1993. This germplasm was selected out of PI 366450. Genetic tests indicate two genes for resistance in this line.

Genetic analysis of control of RWA resistance in wheat and barley is continuing. Parents, F1, backcross, F2, and F2:3 generations are screened and evaluated for segregation ratios. To date, the genetic control of RWA resistance has been determined for six of the resistant wheat lines: PI's 140207 and 225217 have single dominant genes, PI's 149898, 245462, 366515, and 366616 have two genes. Chi-square analysis of the F2 and BC to both parents suggested mutual epistasis between one additive gene which is more expressed, and one dominant gene which is less expressed.

Allelism tests of identified sources of resistance are ongoing; resistant lines are intercrossed, and the F1 is crossed to a susceptible cultivar. Analysis of segregation ratios within the resulting progeny should reveal whether resistance in the two parent lines is controlled by the same or different gene(s).

Cultivar development programs have been initiated: the mission is to incorporate RWA resistance, through a backcrossing program, into wheat and barley of various classifications which are adapted to different areas of the country.

The transfer of RWA resistance genes from the Russian triticales continues. X-ray therapy is being used to induce chromosomal translocations to transfer the resistance gene from PI 386156 (RWA-resistant triticale) to a hexaploid wheat background.

Newly identified sources of RWA resistance continue to be evaluated in the greenhouse for agronomic characteristics and suitability for use in a breeding program.

Publications Since Last Report

Baker, C.A., D.R. Porter, and J.A. Webster. 1993. Inheritance of Russian wheat aphid resistance in a winter wheat - PI 149898. Agron. Abstr., S. Branch, p. 15.

Baker, C.A., D.R. Porter, and J.A. Webster. 1993. Inheritance of Russian wheat aphid resistance in two spring wheats. Agron. Abstr., p. 81.

Baker, C.A., D.R. Porter, and J.A. Webster. Registration of STARS-9302W and 9303W Russian wheat aphid-resistant wheat germplasms. Crop Sci. (In Press)

Baker, C.A., J.A. Webster, and D.R. Porter. 1992. Characterization of Russian wheat aphid resistance in a hard white spring wheat. Crop Sci. 32:1442-1446.

Mornhinweg, D.W., and D.R. Porter. 1993. Effect of Russian wheat aphid on yield and yield components of barley. Agron. Abstr., S. Branch, p. 14.

Mornhinweg, D.W., D.R. Porter, and J.A. Webster. 1993. Inheritance of RWA resistance in barley germplasm line STARS-9301B. Agron. Abstr. p. 95.

Mornhinweg, D.W., D.R. Porter, and J.A. Webster. Registration of STARS-9301B Russian wheat aphid-resistant barley germplasm. Crop Sci. (In Press)

Porter, D.R., C.A. Baker, and D.W. Mornhinweg. 1993. Small grain germplasm enhancement, pp. 10-13. *In* R.L. Burton and J.A. Webster (comp.) The Russian wheat aphid, fifth annual report. U.S. Dep. Agric., Agric. Res. Serv., PSWCL Prog. Rep. 93-009.

Porter, D.R., C.A. Baker, and J.A. Webster. 1993. Russian wheat aphid-induced protein alterations in spring wheat. Agron. Abstr., S. Branch, p. 10.

Porter, D.R., J.A. Webster, and C.A. Baker. 1993. Detection of resistance to the Russian wheat aphid in hexaploid wheat. Plant Breeding 110: 157-160.

RWA-Host Plant Interaction

Mission: To develop a fundamental understanding of the molecular nature of the physiological and biochemical basis of RWA damage to facilitate the development of resistant germplasm derived from both traditional breeding programs and genetic engineering techniques.

Research in support of this mission is broadbased and involves studies both in the laboratory and greenhouse at Stillwater, OK, and in large-scale field plots located at Brookings, SD. Because each unit is studying a different aspect of the interaction phenomena, we have reported their progress separately to assist interested readers who may wish to seek additional specific information directly from the scientists involved.

Unit Mission: To characterize plant physiological and biochemical responses to RWA attack in resistant and susceptible germplasm to identify superior metabolic systems, pathways, or individual components critical to genetic resistance.

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Plant Aphid Interactions
Studies investigating the effect of RWA on carbohydrate physiology in hard red winter wheat (TAM W-101) have shown that aphid infestation greatly reduced total nonstructural carbohydrate accumulation and altered the nonstructural carbohydrate partitioning patterns between root, stem, and leaf tissues. The greatest reductions in nonstructural carbohydrates were observed in root and leaf tissue and resulted primarily from diminished fructan levels. A concomitant decrease of sucrose in the leaves of the infested plants was consistent with the observed whole-plant decline in fructan levels. Related studies measuring transient changes of chlorophyll *a* fluorescence induction kinetics induced by RWA feeding stress indicate that an early event in the damage response involves the inhibition of Q_A- reoxidation. Photoinhibition, characterized by changes in F_O, F_M, F_V, $F_{V/m}$, and F_s, occurs during the first two hours of RWA feeding.

Publications Since Last Report
Belefant-Miller, H.L., D.R. Porter, J.D. Burd, and R.L. Burton. 1993. RWA-host plant interaction: Plant Science Research Laboratory, p. 16. *In* R.L. Burton and J.A. Webster (comp.) The Russian wheat aphid, fifth annual report. U.S. Dep. Agric., Agric. Res. Serv., PSWCL Prog. Rep. 93-009.

Burd, J.D., R.L. Burton, and J.A. Webster. 1993. Evaluation of Russian wheat aphid (Homoptera: Aphididae) damage on resistant and susceptible hosts with comparisons of damage ratings to quantitative plant measurments. J. Econ. Entomol. 86: 974-980.

Miller, H.L. and D.R. Porter. 1993. Physiological effects of Russian wheat aphids on a resistant and susceptible barley. Agron. Abstr., S. Branch. pp. 14-15.

Unit Mission: To study the effect of cropping systems on population dynamics of RWA, and determine how cultural practices affect plant stress and efficiency under RWA infestation.

Walter E. Riedell, Plant Physiologist
Robert W. Kieckhefer, Research Entomologist
David A. Beck, Biological Science Technician
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RWA Control Using Seed and Rescue Treatments
The effectiveness of a diversity of foliar insecticides for cereal aphid control were tested and compared with the pre-plant seed treatment Gaucho 480 FS on field plots of Arapaho winter wheat in October 1993. All of the foliar rescue treatments decimated RWA and other cereal aphid populations on the plants. There was no re-appearance of aphid populations on the plants 26 days after treatment. Gaucho provided equivalent control to all rates of foliar insecticides even at cold temperatures, demonstrating the efficacy of this seed treatment for longterm RWA control.

Impact of Foliar Feeding by Different Aphid Species on Root Growth in Winter Wheat
Previous research from this laboratory has shown that improved nitrogen soil fertility level improves grain yield performance independently of the effects of RWA infestation. To further investigate this phenomenon, an experiment was conducted to elucidate the effect of aphid feeding upon root growth in winter wheat plants. A greenhouse study was run in 1992 where seedling wheat plants were infested with greenbugs, RWAs, or bird cherry-oat aphids for a sum total of 300 aphid days (150 aphids for 2 days, 75 aphids for 4 days, 50 aphids for 6 days, or 25 aphids for 12 days). Plants were evaluated for shoot dry weight, shoot chlorophyll content, and root length. Preliminary results indicate that aphid species that cause leaf chlorosis during feeding (greenbug, RWA) are no more damaging, in terms of reducing root growth, than aphids that do not cause leaf chlorosis (bird cherry-oat aphid). A more complete statistical analysis is underway, and manuscript preparation will take place this year.

Publications Since Last Report
Riedell, W.E., and R.W. Kieckhefer. 1993. Nitrogen fertilizer management and grain yield loss to Russian wheat aphids. Cereal Res. Commun. 21:57-59.

Riedell, W.E., and R.W. Kieckhefer. 1993. RWA-host plant interaction: Northern Grains Insects Research Laboratory, p. 17. *In* R.L. Burton and J.A. Webster (comp.) The Russian wheat aphid, fifth annual report. U.S. Dep. Agric., Agric. Res. Serv., PSWCL Prog. Rep. 93-009.

Insect Genetics

Mission: To conduct national and worldwide biotypic and genetic studies on the RWA and its parasitoids.

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Dr. Kevin A. Shufran will join the PSRL staff in 1994 as a post doctoral Research Associate to continue the research in this area initiated by Dr. Gary Puterka. Dr. Shufran received his Ph.D. from Kansas State University in 1992. His dissertation was on "Phenotypic and Genotypic Variation of Kansas Greenbug (Homoptera: Aphididae) Populations." He has written several publications involving aphid genetics and is well qualified for this position.

Final documentation of previous research results by Dr. Puterka and Dr. Richard Roehrdanz at Fargo, ND, is reported below.

Publications Since Last Report

Puterka, G.J., W.C. Black IV, W.M. Steiner, and R.L. Burton. 1993. Genetic variation and phylogenetic relationships among worldwide collections of the Russian wheat aphid, *Diuraphis noxia* (Mordvilko), inferred from allozyme and RAPD-PCR markers. Heredity 70:604-618.

Roehrdanz, R., D.K. Reed, and R.L. Burton. 1993. Use of polymerase chain reaction and arbitrary primers to distinguish laboratory-raised colonies of parasitic Hymenoptera. Biocontrol 3:199-206.

Biosystematics

Mission: To provide identifications and verifications for RWA and its natural enemies.

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Dr. Stoetzel continued to provide identifications and verifications for *Diuraphis noxia* (Mordvilko). No other activities regarding RWA were reported for 1993.

Publications Since Last Report

Stoetzel, M.B. 1993. Biosystematics, p. 19. *In* R.L. Burton and J.A. Webster (comp.) The Russian wheat aphid, fifth annual report. U.S. Dep. Agric., Agric. Res. Serv., PSWCL Prog. Rep. 93-009.

Biological Control

Mission: To develop a fundamental understanding of the biological and ecological relationships between cereal aphids and their natural enemies in the agroecosystem landscape to facilitate the establishment and integration of biological control strategies into sustainable integrated pest management systems.

This multifaceted mission involves scientific expertise from several laboratories. Each unit's specific mission and accomplishments toward that mission will be reported as separate subsections.

Unit Mission: To develop strategies in the laboratory, greenhouse, and field for maximum utilization of natural enemies (exotic, naturalized, and endemic) in RWA-infested cereals and grasses.

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John D. Burd, Research Entomologist
David K. Reed, Research Entomologist, Retired
Wade French, Biological Science Technician
Brian Jones, Biological Science Technician
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Progress has been made toward developing standardized methods for sampling coccinellids in wheat. Removal sampling provides accurate estimates of adult coccinellids at all densities, and larval coccinellid populations at low and intermediate densities; but at high densities the efficiency of removal sampling is too low to provide useful estimates for larvae. Based on preliminary analysis of the data, it appears that sweepnet sampling is the most useful method for sampling larval coccinellids in wheat. Adult coccinellids are most efficiently sampled by visual counting. Because larval coccinellids are not always sampled adequately by visual counting, the sweepnet may be the best method for sampling adults and larvae simultaneously. A sequential sampling scheme for estimating the mean number of adult coccinellids per 2-minute count with known average precision was developed.

As part of a continuing effort to develop a comprehensive management system for all economically important aphid pests of small grains in the Great Plains region, we measured the effect of greenbug infestations on yield components of early- and late-planted spring wheat in each of two years. Resulting data were used to develop a model relating yield to cumulative greenbug feeding days (aphid-days). A multiple linear regression model that included different intercepts for each spring wheat planting and a common slope relating yield to aphid-days provided a good fit to the data. Based on the model, a loss of 41 kg of grain per ha is expected for each 100 aphid-days that accumulate per tiller. The effect of greenbug and bird cherry-oat aphid infestations on yield components of Karl 92 winter wheat is currently being investigated in field trials; the studies include autumn, spring, and autumn and spring infestations of both species.

Results of a three-year study of the field population dynamics of the RWA in western Nebraska are currently being analyzed. The data were used to validate a simulation model of RWA population dynamics in winter wheat and CRP grass fields. The RWA

population model will be expanded into a spatial population dynamics model for use in exploring the effects of landscape structure on RWA population dynamics and management.

For two successive years we studied the seasonal occurrence and abundance of aphid species in alfalfa, canola, sorghum, red clover, cotton, millet, cultivated sunflower, vetch, and native grasses, as well as on several plant species common to uncultivated lands in the Southern and Central Plains. We identified 16 aphid species whose seasonal abundance patterns indicate that they might effectively serve as alternate host/prey "bridges" for aphidophagous predators and parasitoids for use at times when RWA are typically absent from the agricultural landscape or present in extremely low numbers.

In laboratory tests we found that *Diaeretiella rapae* and *Aphidius colemani* imported for classical biological control of the RWA parasitized individuals of several of the common aphid species to which they were exposed for 24 h on caged host plants. Our results indicate that several of the 16 aphid species that commonly occur in wheat, in crops often grown adjacent to wheat, or in adjacent non-agricultural lands may serve as alternate hosts of these parasitoids. Our results indicate that it may be possible to increase probabilities of establishment of RWA natural enemies by conducting releases at locations where adjacent habitats supporting alternate hosts occur. Results also provide knowledge of hosts and associated habitats into which RWA parasitoids might be released to attempt establishment at times when the RWA is temporarily absent in a particular geographic area. They also indicate a potentially important role for habitat diversification to improve biological control of the RWA (and other economically important cereal aphids) by increasing the availability and predictability of alternate hosts. Our results provide no evidence to suggest that inability to rapidly adapt to new hosts will limit the value of habitat diversification as an approach for increasing the effectiveness of these parasitoids in biological control of the RWA in the Great Plains. We are currently conducting similar studies with several geographic isolates of *Aphelinus asychis* and *A. sp. nr. varipes* from Asia.

A system has been successfully devised for the incorporation of radio-labeled markers into RWAs, greenbugs, and their natural enemies. This technique has been adapted for use in both field and greenhouse research, and studies are currently underway to determine RWA natural enemy dispersal patterns, host selection, and efficacies (including competition) in multitrophic systems.

Caged releases consistently resulted in better (greater natural enemy population densities) colonization of release sites than open-field releases. In southeastern Colorado in 1992, caged releases in wheat fields resulted in greater population densities of natural enemies in colonization surveys than releases into CRP. During spring and summer of 1993, 1.23 million RWA natural enemies were released at five locations in eastern Colorado. Releases were made in cooperation USDA, APHIS and the

Colorado Department of Agriculture.

We have expanded our capabilities for quantitative study and simulation modeling by establishing a laboratory with Geographic Information System (ERDAS) and Artificial Intelligence capabilities. We are currently in the process of obtaining, organizing, and analyzing remotely sensed spatial data and constructing spatially explicit habitat suitability maps for the RWA in southeastern Colorado.

Research on interactions among cereal hosts, RWA, and natural enemies are continuing. Research on interactions of entomophagous fungi, resistant and susceptible wheat, and RWA is in the final stages. Tritrophic effects on wheat grasses have been published, and work on long-term tritrophic effects and field tritrophic research in continuing.

A visiting scientist from Oral Roberts University, Dr. H.C. Reed, conducted research on olfactory cues to a common RWA parasitoid, *Diaeretiella rapae*, using a wind tunnel and olfactometer. His work has provided a great deal of preliminary information that will lead to further research this year. An in-house laboratory report and two student reports have been written concerning the research.

We determined thermal thresholds for development of exotic *A. colemani* and *D. rapae*. Lower thermal thresholds are similar to that of the RWA, suggesting that low temperatures may not impose a barrier to population growth by these parasitoids.

We assessed the ability of *Cycloneda ancoralis* to successfully complete development on four aphid species (*Aphis gossypii, A. helianthi, Diuraphis noxia,* and *Lypaphis erysimis*) common in Great Plains agroecosystems. Results indicate that the coccinellid can complete immature development on all four species, but the species differ qualitatively as a food source for the coccinellid. While the ability to survive on a broad range of prey is insufficient to ensure that the coccinellid can establish and contribute to biological control of *D. noxia* and other cereal aphids, it is a desirable characteristic for successful exploitation of this agroecosystem.

Mummy weight, an easily obtained biological parameter often used as a measure of parasitoid robustness/fitness, was shown to be unreliable due to variance among growth stages. This variance can be eliminated with proper experimental protocols.

Field overwintering studies conducted in Oklahoma in 1990 and 1991 indicate that Soviet and Syrian *D. rapae*, South American *A. asychis* and *A. colemani*, and South American *C. ancoralis* and *H. variegata* can overwinter successfully in some winters. These studies are continuing.

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Unit Mission: To import, quarantine, test, ship, release, and establish exotic natural enemies (parasites and predators) for use in classical biological control programs for the RWA.

Lawrence R. Ertle, Entomologist
Paul W. Schaefer, Research Entomologist
Roger Fuester, Research Entomologist
Ken Swan, Biological Science Technician
Susan Barth, Biological Science Technician
USDA, ARS Beneficial Insects Introduction Research (BIIR)
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Newark, DE 19713
302-731-7330, FAX 302-737-6780

No activities pertaining to RWA were reported for 1993.

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Ertle, L.R., P.W. Schaefer, and R. Fuester. 1993. Biological control: Beneficial Insects Introduction Research Laboratory, pp. 27-28. *In* R.L. Burton and J.A. Webster (comp.) The Russian wheat aphid, fifth annual report. U.S. Dep. Agric., Agric. Res. Serv., PSWCL Prog. Rep. 93-009.

Unit Mission: To develop fungal pathogens of RWA, devise strategies for the introduction of fungi for RWA control in the field, and provide taxonomic support to other scientists studying RWA pathogens.

John D. Vandenberg, Research Entomologist
Jennifer McManus, Biological Science Technician
Richard A. Humber, Microbiologist
USDA, ARS Plant Protection Research Unit (PPRU)
U.S. Plant, Soil and Nutrition Laboratory
Tower Road
Ithaca, NY 14853-0331
607-255-0496, FAX 607-255-2459

Using the newly-completed (late 1992) insect quarantine facility, T.J. Poprawski conducted preliminary screening of eleven species of fungi (45 isolates) against the RWA in laboratory bioassays during early 1993. A study to test tritrophic interactions among aphids, their host plants, and aphid-pathogenic fungi was done in cooperation with ARS researchers in Stillwater, OK. Partial results indicate that fungus activity is more limited when aphids feed on resistant plant varieties. Details and results of these tests may be obtained from T.J. Poprawski at his new address (c/o USDA ARS Biological Pest Control Research, 2413 E. Highway 83, Weslaco, TX 78596.)

In late 1993, a quantitative bioassay method was developed for testing various fungi against the RWA in the laboratory. Surface-sterilized cut leaves of barley are embedded in agar under aseptic conditions. Known-aged adults are placed on these leaves and then exposed to fungus spore showers. Aphids and their offspring are monitored daily for survival or infection. This method minimizes aphid handling while facilitating observation and data collection. Quantitative comparisons among fungi and among aphid populations treated in various ways are currently underway. Factors being evaluated include fungus species and isolate, aphid age, temperature, and host plant variety.

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Wraight, S.P., T.J. Poprawski, W.L. Meyer, and F.B. Peairs. 1993. Natural enemies of Russian wheat aphid (Homoptera: Aphididae) and associated cereal aphid species in spring-planted wheat and barley in Colorado. Environ. Entomol. 22:1383-1391.

Unit Mission: To collect, study, and import natural enemies of the RWA.

Keith R. Hopper, Research Entomologist
Lawrence A. Lacey, Insect Pathologist
David J. Kazmer, Research Entomologist
FSN Staff: Kim Chen
Dominique Coutinot
Guy Mercadier
Gerhild Kirk
Valerie Noel
Natalie Ramualde-Serviat
Students: Antonio Mesquita
Remi Dabire
Xavier Fauvregue
Angela Nobrega-Farias
Visiting Scientist: Peter Mason, Agriculture Canada
USDA, ARS European Biological Control Laboratory (EBCL)
Montpellier, France
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We explored and collected in France, Italy, Greece, and Spain. From these collections, we reared and shipped 7,936 predators and parasitoids from 19 cultures to US quarantines and on to cooperators for release.

Isolates of the fungal pathogens *Paecilomyces fumosoroseus, Verticillium lecanii*, and *Beauvaria bassiana* proved promising in bioassays against *D. noxia.* Studies on the interaction of fungi and *Aphelinus asychis* are also underway.

In a field exclosure experiment in Colorado, *D. noxia* was 12-fold higher with native natural enemies excluded, but releases of predators and parasitoids did not reduce *D. noxia* density. Similar exclosure experiments were conducted by Z. Basky at the Crop Protection and Soil Conservation Station, Szolnok, Hungary, but the results have not yet been analyzed.

Sampling of *D. noxia* and natural enemy population dynamics was continued. There continue to be two population peaks in the Montpellier area, one in the spring and the other in autumn. As of yet, no sexual reproduction has been found. In the field in France, *D. noxia* density was 16-fold higher with natural enemies excluded. A peak of 25% of *D. noxia* exposed in the field were parasitized by six parasitoid species.

In laboratory experiments, *Leucopis* sp. oviposition depended on *D. noxia* density, three times more eggs were laid on rolled leaves than on open leaves, and *Leucopis* sp. consumed on average 11 aphids during larval development.

Odors from *D. noxia*, barley, and *D. noxia* plus barley attracted female *A. asychis* (field-collected and laboratory-reared) no more than pure air. In laboratory experiments, *A. asychis* males searched significantly more on plants marked by the females with a contact pheromone than on unmarked plants. A mathematical model of male mating behavior explained sex ratio observed in the field.

To determine the genetic basis of traits likely to affect field fitness, we measured juvenile survival, development time, sex ratio, handling time, acceptance, walking speed, flight propensity, longevity, fecundity, and morphology for the F_1 progeny of a diallel cross of isofemale lines of *A. asychis* that have been inbred for over 50 generations. Initial analysis indicated no significant differences between lines in walking speed or flight propensity. However, inbred lines walked more slowly and flew less than outbred lines. Further analyses of these data are in progress.

The suitability of using the randomly amplified polymorphic DNA-polymerase chain reaction (RAPD-PCR) technique as a source of genetic markers for natural enemy release experiments and gene flow studies was investigated. A large number of polymorphic markers (32 variants among 142 total bands) were found in six isofemale lines of *A. asychis* started from the same field. Thus, this technique provides abundant markers in a situation where an alternative technique, allozyme electrophoresis, usually fails for many haplodiploid parasitoids. However, heritability studies indicate that artifactual DNA banding patterns are relatively common in diploid females and this, combined with the dominance of RAPD markers, generally limits the utility of RAPD-PCR to haploid males. In addition, RAPD markers generated by the same primer are often strongly linked and consequently gene flow studies should employ a large number of primers to minimize the effects of marker nonindependence/linkage.

The effects of laboratory mass-rearing on selected fitness components of *A. asychis* were examined using replicated "new" (F_2) and "old" (F_{21}) mass-rearings. Preliminary analyses indicate that parasitoids from the new mass-rearings are smaller than those from the old mass-rearings. When size differences are taken into account, fitness measures including egg load, longevity, flight propensity, and walking speed do not differ significantly between the new and old mass-rearings. Additional experiments are underway to determine if the larger size of parasitoids in the old mass-rearings is a result of adaptation to laboratory conditions.

A project on geographical variation in cold tolerance of *D. noxia* parasitoids was started with Dr. P. Mason, Agriculture Canada.

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